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Digital innovation and the fourth industrial revolution: epochal social changes?

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Abstract ITC technologies have come to comprehensively represent images and expectations of the future. Hopes of ongoing progress, economic growth, skill upgrading and possibly also democratisation are attached to new ICTs as well as fears of totalitarian control, alienation, job loss and insecurity. Currently, with the terms "Industry 4.0." and 'Fourth Industrial Revolution" (FIR), public institutions (such as the national governments of Germany, Us, Italy, France, and Hollande), private institutions (the World Economic Forum, Hedge Funds, commercial banks), and literature refer to the inchoate transformation of production of goods and services resulting from the application of a new wave of technological innovations: interconnected collaborative robots; machine learning; Artificial Intelligence; 3D printers connected to digital development software; simulation of interconnected machines; integration of the information flow along the value chain; multidirectional communication between manufacturing processes and products (Internet of Things). According to the main representations of Industry 4.0. by private and public institutions, its effects are expected to be mainly positive, for what regards productivity, economic opportunities and the future of work. The positive potentials now attributed to the new cycle of innovation evoke and expand those attributed to the previous waves of innovation linked to ITC technologies, and, even before, to the transition from Fordism to Post-Fordism. However, these transformations have so far not achieved any of the promises they raised. Improvements for workers in terms of work conditions, work performance and work relationships cannot be determined by any technical innovation in itself, being technological innovation always socially shaped.

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1 Digital innovation and the fourth industrial revolution: epochal social changes?

In 1979, the futurist Alvin Toffler popularized the concept of a new information era underpinned by several key ideas, including the demassification of media, the end of mass production and mass consumption, customised products and services, decentralisation, interactivity and full but hyper-flexible employment.

ITC technologies have come to comprehensively represent images and expectations of the future. Hopes of ongoing progress, economic growth, skill upgrading and possibly also democratisation are attached to new ICTs as well as fears of totalitarian control, alienation, job loss and insecurity (Garibaldo 2016; Castells 2000; Holtgrewe 2014; Fuchs 2010, 2012).

Currently, with the terms Industry 4.0. and 'Fourth Industrial Revolution" (FIR), public institutions (such as the national governments of Germany, Us, Italy, France, and Hollande), private institutions (the World Economic Forum, Hedge Funds, commercial banks), and literature (Edwards and Ramirez 2016; Hirsch-Kreinsen 2016; Kelly 2015), refer to the inchoate transformation of production of goods and services resulting from the application of a new wave of technological innovations.

The essential element of this transformation is considered to be the intersection between production, processing processes and flows of information online (Internet of Things, cloud, Big Data), and devices (sensors, chips) that communicate independently with each other along the entire value chain. Firms would establish global networks that incorporate their machinery, warehousing systems and production facilities in the shape of cyber-physical systems (CPS).

According to the main representations of Industry 4.0. by private and public institutions, its effects are expected to be mainly positive, for what regards productivity, economic opportunities and the future of work. According to the World Economic Forum, the 'Fourth Industrial Revolution' has the potential to raise global income levels and improve the quality of life for populations around the world. Workers will be greatly benefited by it. In the light of the impending shortage of skilled workers, older workers could extend their working lives. Flexible work organization would enable workers to combine their work and private lives to continue professional development more effectively, thus promoting a better work-life balance.

The social consequences of the project "Industry 4.0", such as the problem of unemployment and the composition of the labour market in terms of professional skills, are kept in the background (Garibaldo 2016; Hirsch-Kreinsen 2014). Critical views on these institutional narratives mainly point out two problematic issues. First, technological determinism is questioned. Technologies are not exogenous to social structures, but they are embedded in social and power relationships, and they are not neutral, but open to certain social options and closed to others (Noble 1986; Garibaldo 2016). Second, effects of technology on unemployment, work conditions and work organization are not predictable (Farrell and Greig 2016).

The processes, mechanisms, opportunities and threats that literature has been attributing during the last years to ITC, digital economy and "knowledge economy"—and more in general to the consequences of digital technologies on work and production—are now made even more radical in the current representations of Industry 4.0. by public and private institutions.

The positive potentials now attributed to the new cycle of innovation evoke and expand those attributed to the previous waves of innovation linked to ITC technologies, and, even before, to the transition from Fordism to Post-Fordism. Theories on ITC mainly framed the new phase of capitalism as knowledge based economy (KBE), considering digital technologies and organizational transformations in capitalism to be at the origin of a general societal change, alternately defined as knowledge-based society (Stehr 1994), virtual society, Internet society (Bakardjieva 2005), network-society (Castells 1996), cybersociety (Jones 1998), and informational or digital capitalism (Fuchs 2010 and 2012). These definitions refer to the idea that production processes related to ITC determine a decisive discontinuity between modern society and contemporary society. Stehr (1994) argued that "knowledge age" puts an end to the age of labour and property, Drucker (2001) that work, workforce, society and politics will assume forms that humanity has never experienced, Florida (2012) that the distinction between capitalists and proletariat becomes outdated.

According to Holgrewe (2013):

> The information and communication technology (ICT) sector is probably the sector that is most emblematic of society-wide progress and innovation, both technologically and economically. Indeed, practices of technology use, employment and work organization in the sector often pioneer developments in other sectors. The obvious reason is that this sector develops a large proportion of the technologies that visibly change work and life throughout societies and economies. It builds its practices on the self-applications of its own inventions. Simultaneously, these technologies diffuse into other sectors and spheres of society, both changing these contexts and being adapted to them.

Representations on the consequences of Industry 4.0. and the 'Fourth industrial revolution' are very similar to those linked to post-Fordism, knowledge economy and the "New economy" or "Internet economy", which mainly predicted: the creation of decentralized production networks heralding a turning point in industrial production, particularly for what regards the balance of power between large and small companies; the blurring of boundaries between industry and services and between production and consumption; the growth in autonomy and creativity of work performances and in decision-making capacity by workers (Adler 1992; Kelly 1998; Florida 2012). Such changes in workers' performances then would serve to ensure significant increases in productivity and to arrange processes where the driving forces are fast problem-solving abilities, creativity, cognitive, linguistic and social skills of workers, as well as their full involvement in the working process. Excessively hierarchical structures and overly strict control over labour, according to these views, impede production and the spread of knowledge and information. These changes in work performance and organisation would regard both manual and non-manual work, the industrial and the service sector, as all of them are in different ways affected by the current centrality of information, knowledge, communication and data within production processes.

In the current representations of Industry 4.0., the nexus between technological innovation and horizontal decision-making, diffusion of responsibilities, and the increase in autonomy, creativity and skill equipment among workers, is further extended. According to the "Final Report of the Industrie 4.0 Working Group" sponsored by the German Federal Ministry for Education and Research (BDI and Berger 2013):

> Employees will be supported in their work by smart assistance systems with multimodal, user-friendly user interfaces. In addition to comprehensive training and CPD measures, work organisation and design models will be key to enabling a successful transition that is welcomed by the workforce. These models should combine a high degree of self-regulated autonomy with decentralised leadership and management approaches. Employees should have greater freedom to make their decisions, become more actively engaged and regulate their workload

According to most literature on knowledge based economy, digital capitalism, and techno-optimist narratives on the fourth industrial revolution, mankind will become largely freed of the burden of hard manual work, and autonomy and creativity of the working people will be unbundled as the FIR will create a set of technological slaves, that is machines and robots capable of responding to vocal commands or following unplanned behaviour oriented to a functional purpose. Thus, the capacity to manipulate symbols—specifically of a logical-mathematical kind—would become the guiding value behind the new specialised laboratories. Knowledge workers, the ones who will organise and run the working processes and will constitute the new elite, based on merit and not on social classes or the control of capital.

Do these representations, in the current scenario, correspond to real phenomena? This is the question at the heart of this work that aims to analyze the impact—current and potential—of technological innovation on work. First, a review will be made of the institutional representations on Industry 4.0, on the basis of the official reports produced by public and private institutions. Second, the state of the art on 'digital work' will be analyzed, based on existing literature and evidence. Being the process of Industry 4.0. still incipient and its impact on work still largely unpredictable, an analysis of its possible consequences can only focus on the current scenario, that is, on the ongoing trends and the already observable consequences of digital technologies on work. The analysis will be concentrated on the relationship between academic and institutional rhetoric on Industry 4.0. and digital capitalism—which, as we have already seen, strictly evokes and expands previous rhetoric on post-Fordism knowledge based economy—and the empirical evidence on digital work.

2 Institutional and corporate narratives on industry 4.0

Industry 4.0. is considered to be part of the wider 'digital economy'. According to Degryse (2016), a great part of the outlines emerging from the literature on digital economy, such as the arrival of the information and knowledge economy, are long-heralded but have recently undergone a reinterpretation, whereas others were debated in the substantial body of literature published on the new economy or digital economy around the first decade of the new century. These outlines can be summarized as follows:

1. Digitised information has become a strategic resource, and the network has become the chief organising principle of the economy and society as a whole.
2. The digital economy follows the principles of growing returns (positive network externalities) and zero or quasi-zero marginal costs.

   Criticisms have been made to this principle. First, it focuses exclusively on positive network externalities and ignores negative externalities, in particular environmental concerns such as the consumption of electricity and scarce mineral resources and the production of electronic waste. Moreover, the gains in efficiency and profitability generated by technological investment in any technical system are initially very high, but then decline and become increasingly incremental as the innovation becomes widespread. In the long term, this technological 'burn-out' means that innovations deliver diminishing returns until the technical systems are regenerated by radical innovations (Valenduc and Vendramin 2016).
3. New business models are springing up to take advantage of two-sided markets and the platform-based economy, particularly those involving collaboration or sharing, and new competitive dynamics—dominated by the 'winner takes all' model—are taking hold in markets for digital goods and services. The platform itself is, therefore, the primary location of value creation for both sides. The value of a service for the actors on one side of the market correlates to the number and quality of the actors on the other. Examples of platforms which correspond to this description include Google, Booking, Uber, Amazon and many others. The newly developed platform-based business model has rewritten the rules of competition in the market sectors in which these platforms operate by promoting a 'winner takes all' approach (Brynjolfsson and McAfee 2015).
4. Industry 4.0. involves short production runs of mass-customised goods, the global fragmentation of value chains, the networking of productive capacities and the

blurring of boundaries between producers, sellers and consumers on the one hand and industry and the services sector on the other.

5. Cause-and-effect link between technological innovation and productivity gains has not yet been directly established, and the relationship between technology and productivity is still heavily dictated by society's take-up of innovations and organizational changes within companies.

Let us focus on the point of greatest interest for this work, point 4 on Industry 4.0., summarizing the main perspectives included in the institutional reports on this subject.

The innovation process defined as Industry 4.0. or the FIR is based on a new wave of technological innovations: interconnected collaborative robots; machine learning; Artificial Intelligence; 3D printers connected to digital development software; simulation of interconnected machines; integration of the information flow along the value chain, from the supplier to the consumer; multidirectional communication between manufacturing processes and products (internet of things); management of large amounts of data on open systems (cloud computing); and analysis of large databases to optimize products and processes (big data and analytics).

The final goal of Industry 4.0 is that of reaching a new level of automation based on decentralised and smart parts of the production chain, that are able to autonomously react to external stimuli. The aim of this conception is to manage the increasing flexibility demands of end-markets, an increasing individualization of products, ever-shorter product life-cycles, as well as the increasing complexity of process chains and the products themselves (Garibaldo 2016, Hirsch-Kreinsen 2016). In other words, the existing technological and economic limits of automation are to be broken and extended precisely in response to the new demands posed by flexibility (Hirsch-Kreinsen 2014, Hermann et al. 2015). Industry 4.0. is, therefore, a project of integration of production over the entire value chain. The tight flow is achievable through the digital connection of the different parts of the production line, not only the one internal to the company but of the entire supply chain; the connection would not be only between machines but between machines and men (Farrell and Greig 2016).

According to the main descriptions on the possible scenarios, in the manufacturing environment, Cyber-Physical Systems will comprise smart machines, storage systems and production facilities capable of autonomously exchanging information, triggering actions and controlling each other independently. More in general, computational design, additive manufacturing, materials engineering, and synthetic biology are going to be combined to pioneer a symbiosis between microorganisms, our bodies, the products we consume, and even the buildings we inhabit.

According to the World Economic Forum's study (2016):

> A fourth industrial revolution is building on the third, the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres. There are three reasons why today's transformations represent not merely a prolongation of the Third Industrial Revolution but rather the arrival of a Fourth and distinct one: velocity, scope, and systems impact. The speed of current breakthroughs has no historical precedent. When compared with previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear pace. Moreover, it is disrupting almost every industry in every country. And the breadth and depth of these changes herald the transformation of entire systems of production, management, and governance.

According to the Us Government Report (2016),

> Robots have made the economy more efficient. A 2015 study of robots in 17 countries found that they added an estimated 0.4% point on average to those countries' annual GDP growth between 1993 and 2007, accounting for just over one-tenth of those countries' overall GDP growth during that time. Some of that growth has been achieved by U.S. manufacturers adopting robots, allowing more goods to be produced while employing fewer workers at some facilities. AI in its many manifestations also holds promise to transform the basis of economic growth for countries across the world; a recent analysis of 12 developed economies (including the United States) found that AI has the potential to double annual economic growth rates in the countries analyzed by 2035.

According to the report commissioned by the German Government (BDI and Berger 2013)

> Industrie 4.0 holds huge potential. Smart factories allow individual customer requirements to be met and mean that even one-off items can be manufactured profitably. In Industrie 4.0, dynamic business and engineering processes enable last-minute changes to production and deliver the ability to respond flexibly to disruptions and failures on behalf of suppliers, for example. End-to-end transparency is provided over the manufacturing process, facilitating optimised decision-making. Industrie 4.0 will also result in new

> ways of creating value and novel business models. In particular, it will provide start-ups and small businesses with the opportunity to develop and provide downstream services. In addition, Industrie 4.0 will address and solve some of the challenges facing the world today such as resource and energy efficiency, urban production and demographic change

On the whole, according to these views the effects that the Fourth Industrial Revolution might have on business regard four main domains: (a) customer expectations; (b) product enhancement; (c) collaborative innovation; (d) organizational forms. According to the institutional descriptions of the inchoate FIR, customers are increasingly at the epicenter of the economy, which is all about improving how customers are served. Physical products and services can now be enhanced with digital capabilities that increase their value. New technologies make assets more durable and resilient, while data and analytics are transforming how they are maintained. A world of customer experiences, data-based services, and asset performance through analytics, meanwhile, requires new forms of collaboration, particularly given the speed at which innovation and disruption are taking place. And the emergence of global platforms and other new business models, finally, means that talent, culture, and organizational forms will have to be rethought (Schwab 2015).

Industry 4.0. would imply a double process of horizontal and vertical integration (Italian Government Report 2016). In the fields of production and automation engineering and IT, horizontal integration refers to the integration of the various IT systems used in the different stages of the manufacturing and business planning processes, that involve an exchange of materials, energy and information both within a company (e.g. inbound logistics, production, outbound logistics, marketing) and between several different companies (value networks). The goal of this integration is to deliver an end-to-end solution. In the fields of production and automation engineering and IT, vertical integration refers to the integration of the various IT systems at the different hierarchical levels (e.g. the actuator and sensor, control, production management, manufacturing and execution and corporate planning levels) in order, once again, to deliver an end-to-end solution (Zysman and Kenney 2014, Edwards and Ramirez 2016, Magone and Mazali 2016).

The German Report states that Industry 4.0. has these potentials: (a) *meeting individual customer requirements*. Industry 4.0 would allow individual, customer-specific criteria to be included in the design, configuration, ordering, planning, manufacture and operation phases and enables last-minute changes to be incorporated; (b) *flexibility*. CPS-based ad hoc networking enables dynamic configuration of different aspects of business processes. It means that engineering processes can be made more agile, manufacturing processes can be changed, temporary shortages (e.g. due to supply issues) can be compensated and huge increases in output can be achieved in a short space of time. (c) *Optimised decision-taking*. Industry 4.0 provides end-to-end transparency in real time, allowing early verification of design decisions in the sphere of engineering and both more flexible responses to disruption and global optimisation across all of a company's sites in the sphere of production. (d) *Resource productivity and efficiency*. CPS allows manufacturing processes to be optimised on a case-by-case basis across the entire value network. Moreover, rather than having to stop production, systems can be continuously optimised during production in terms of their resource and energy consumption or reducing their emissions. (e) *Creating value opportunities through new services*. Industry 4.0 opens up new ways of creating value and new forms of employment, for example through downstream services. Smart algorithms can be applied to the large quantities of diverse data (big data) recorded by smart devices to provide innovative services. There are particularly significant opportunities for SMEs and startups to develop B2B (business-to-business) services for Industry 4.0. (f) *Responding to demographic change in the workplace*. In conjunction with work organisation and competency development initiatives, interactive collaboration between human beings and technological systems will provide businesses with new ways of turning demographic change to their advantage. In the face of the shortage of skilled labour and the growing diversity of the workforce (in terms of age, gender and cultural background), Industry 4.0 will enable diverse and flexible career paths that will allow people to keep working and remain productive for longer. (e) *Work-life-balance*. The more flexible work organisation models of companies that use CPS mean that they are well placed to meet the growing need of employees to strike a better balance between their work and their private lives and also between personal development and continuing professional development. Smart assistance systems, for example, will provide new opportunities to organise work in a way that delivers a new standard of flexibility to meet companies' requirements and the personal needs of employees.

According to the Dutch Report on smart industries (2016), carried out by a network of large firms, the turning point is constituted by the Internet of Things:

> It will decentralise production by enabling flexible, programmable and embedded forms of manufacturing. Real time Machine-to-Machine communication offered by the IoT will synchronise complex, high-end production systems, creating highly innovative

> value chains that cut across traditional sectors and domains. Advanced forms of manufacturing will drive the design of new materials, blurring the line between manufacturing and assembly, and Smart Industry will give a great push to lifecycle management and recycling.

Knowledge and information—as the literature on ITC technologies affirms since the late Seventies (Toffler 1979)—will be the key factors:

> Based on the next step in digitalization, a focus of business could be the use of information as a new source of value creation, since sensors and the network-centric approach will lead to an overwhelming amount of data. This information can be used to further align the activities within the value chain and improve communication between players. It can also be used to increase product qualities with new added services. With the help of smart sensors and IT, the manufacturer can predict the need for maintenance and can help customers all over the world with IT updates. The collection of all kinds of data (for example about the environment) can be translated into groups of new and unexpected (cross-sector) services (Dutch Report on Smart Industry 2016)

According to the WEF, "In the future, technological innovation will also lead to a supply-side miracle, with long-term gains in efficiency and productivity. Transportation and communication costs will drop, logistics and global supply chains will become more effective, and the cost of trade will diminish, all of which will open new markets and drive economic growth". According to the Us Government report on artificial intelligence and the economy (Arntz et al. 2016), "AI-driven automation could help boost total factor productivity growth and create new potential to improve the lives of Americans broadly".

For what regards work, according to these institutional reports, implementation of the Industry 4.0 vision will enable employees to control, regulate and configure smart manufacturing resource networks and manufacturing steps based on situation—and context—sensitive targets. Employees will be freed up from having to perform routine tasks, enabling them to focus on creative, value-added activities. They will thus retain a key role, particularly in terms of quality assurance. At the same time, flexible working conditions will enable greater compatibility between their work and their life (Italian Government Report 2016). Work organization and design models will be key to enabling a successful transition that is welcomed by the workforce. These models should combine a high degree of self-regulated autonomy with decentralized leadership and management approaches. Employees should have greater freedom to make their own decisions, become more actively engaged and regulate their own workload. We thus have a further confirmation that from the point of view of work, the rhetoric concerning Industry 4.0. are the same as those relating to post-fordism, the knowledge-based economy and digitization.

Let us move to the issue of unemployment. This is the only point on which the optimistic forecasts of public and private institutions on the new innovation cycle show some uncertainty, although in a context aiming at highlighting opportunities more than risks. The Organisation for Economic Cooperation and Development (Arntz et al. 2016), highlights that automation targets tasks rather than occupations. Many occupations are likely to change as some of their associated tasks become automatable, so the OECD analysis concludes that relatively few will be entirely automated away, estimating that in Usa only 9% of jobs are at risk of being completely displaced. If these estimates of threatened jobs translate into job displacement, millions of Americans will have their livelihoods significantly altered.

The USA government report has identified four categories of jobs that might experience direct AI-driven growth in the future. Employment in areas where humans engage with existing AI technologies, develop new AI technologies, supervise AI technologies in practice, and facilitate societal shifts that accompany new AI technologies will likely grow. Current limits on manual dexterity of robots and constraints on generative intelligence and creativity of AI technologies likely mean that employment requiring manual dexterity, creativity, social interactions and intelligence, and general knowledge will thrive.

The World Economic Forum's study predicts that 5 million jobs will be lost before 2020 as artificial intelligence, robotics, nanotechnology and other socio-economic factors replace the need for human workers. According to this study, those same technological advances will also create 2.1 million new jobs. But the manual and clerical workers who find themselves out of work are unlikely to have the required skills to compete for the new roles. Most new jobs will be in more specialized areas such as computing, mathematics, architecture and engineering. Soft skills such as sharing and negotiating will be crucial. The future workplace, where people move between different roles and projects, closely will resemble pre-school classrooms, where to learn social skills such as empathy and cooperation.

According to Deming (2016), in recent years, many jobs requiring only mathematical skills have been automated. Bank tellers and statistical clerks have suffered. Roles which require predominantly social skills (childcare workers, for example) tend to be poorly paid as the supply of potential workers is very large. Therefore, workers who successfully combine mathematical and interpersonal skills in the knowledge-based economies of the future should find many rewarding and lucrative opportunities. This kind of worker looks like an empathic robot.

CEA ranked occupations by wages and found that, in USA, 83% of jobs making less than $20 per hour would come under pressure from automation, as compared to 31% of jobs making between $20 and $40 per hour and 4% of jobs making above $40 per hour. The OECD study estimates that less-educated workers are more likely to be replaced by automation than highly educated ones. Indeed, the OECD study's authors estimate that 44% of American workers with less than a high school degree hold jobs made up of highly automatable tasks, while 1% of people with a bachelor's degree or higher hold such a job. To the degree that education and wages are correlated with skills, this implies a large decline in demand for lower-skilled workers and little decline in demand for higher-skilled workers. These estimates suggest a continuation of skill-biased technical change in the near term. This will give rise to a job market increasingly segregated into "low-skill/low-pay" and "high-skill/high-pay" segments, which in turn will lead to an increase in social tensions.

Technology is one of the main reasons why incomes have stagnated, or even decreased, for a majority of the population in high-income countries: the demand for highly skilled workers has increased while the demand for workers with less education and lower skills has decreased. The result is a job market with a strong demand at the high and low ends, but a hollowing out of the middle. It also helps explain why middle classes around the world are increasingly experiencing a pervasive sense of dissatisfaction and unfairness. A winner-takes-all economy that offers only limited access to the middle class is a recipe for democratic malaise and dereliction.

Research, according to these institutional studies, consistently finds that the jobs that are threatened by automation are highly concentrated among lower-paid, lower-skilled, and less-educated workers. This would mean that automation will continue to put downward pressure on demand for this group, putting downward pressure on wages and upward pressure on inequality. In the longer-run, there may be different or larger effects. One possibility is superstar-biased technological change, where the benefits of technology accrue to an even smaller portion of society than just highly skilled workers. The winner-take-most nature of information technology markets means that only a few may come to dominate markets. According to the USA Report, if labor productivity increases do not translate into wage increases, then the large economic gains brought about by AI, learning machines and other technologies could accrue to a select few. Instead of broadly shared prosperity for workers and consumers, this might push towards reduced competition and increased wealth inequality.

3 Digital economy, digital work and their ambivalences

Let us see, in the light of the literature and evidence available on the current scenario of digital work, the criticisms that can be made to the institutional perspectives on work at the time of the 'Fourth Industrial Revolution', and to the main assumptions included in the institutional reports.

A first issue concerns technological determinism. Institutional reports and mainstream literature make process, product and organizational innovations, and the restructuring of the business cycle, directly and immediately derive from the nature itself of technologies, as if the latter were autonomous from the existing social relationships between the productive forces. On the contrary, the effects of technologies on jobs and organizations have to be considered socially shaped.

According to Sabel and Zeitlin (1985: 176) 'it is the politics, and not the immanent characteristics of the technologies that will decide how new machines are designed' (see also Garibaldo 2016, Edwards and Ramirez 2016). Technology is often used as a pretext or opportunity to push through industrial restructuring processes motivated primarily by financial profitability, wage cost reduction or international competition considerations (Valenduc and Vendramin 2016, Freeman and Soete 1994).

Moreover, technological innovations do not predict any prescribed consequence on jobs and organization in themselves. Orlikovski (1992) identifies three dimensions: (1) *intended or unintended effects*. Some technologies are introduced with clear ends in view. In other cases, effects result from the interaction between forces of production and social processes. (2) *Direct or indirect effects*. Many technologies have effects that are indirect in two senses. First, they affect workers who are not themselves subject to the technology, for example, where an assembly line is accompanied by changes to the work of people in ancillary operations. Second, effects may contribute to wider organisational arrangements. The more that there are such effects, the more complex the issue of how to respond will be. This idea embraces how pervasive a technology is in terms of its overall impact on the economic system. Some technologies have specific applications, whereas others such as ICTs are extremely pervasive. (3) *The degree to which a technology is reconstituted in use*. It is not the technology in itself, but the *extent* of its use that alter. Reconstitution can mean that the *nature and application* of the technology alter. A conventional phone is not reconstituted in use, as all that can be done with it is to make calls. A smart phone is more likely to be reconstituted because it has broader and more flexible properties (Edwards and Ramirez 2016).

Not even the link between technological innovation and increased productivity can be taken for granted, as the institutional reports on Industry 4.0. do. First, large firms investing in ITC technologies record increased productivity, but these investments just determine micro-economic effects, because these gains come at the expense of companies which are less efficient investors. Second, there is a gap between exponential growth in technological performance on the one hand and the slower rate at which innovations are adopted and appropriated by companies and other organisations on the other. A technology must ne 'everywhere' before its impact on productivity can be assessed. Third, Productivity gains are a corollary of the organisational changes facilitated by technological innovations rather than the technologies themselves, and will be achieved only by companies which adopt new forms of work organisation at the same time as the new technologies (Valenduc and Vendramin 2016; Askénazy and Gianella 2000).

Let us move to the issue of digital work. For what regards work organization, an interpretation largely shared by most perspectives on new technologies and knowledge-based work, establishes a narrow link between the current innovation cycle and the formation of a new kind of business organisation. The most frequently used metaphor is that of the 'network-firm': within firms self-managed process units, project teams, temporary organisations that produce and manage innovation and problem-solving processes develop. Large corporations are even termed 'project-based organizations' or 'multi-project environments'. Projects are temporary configurations of (human) resources situated within a larger 'permanent' organization, where individuals have other 'homes' before, during and after being involved in this temporary organization (Yeow 2014, Lundin and Söderholm 1995). Employees and freelancers—due to ITC technologies—can take part in several projects simultaneously, for one or more firms, potentially assuming different roles and responsibilities in each one. This, according to some, individualize labour relationships and can help workers become more autonomous with respect to firms. Information and knowledge as inputs and outputs of the work process, according to these views, resist formalised and rigid processes, while functional to their development is the presence of 'communities' within the organisation that create a sense of identity and the sharing of values and purposes, partly self-managed cooperation processes, modes of knowledge circulation and sharing, and intensification of internal and external communication.

This would have important consequences for one of the main components of the capitalist mode of production. Vercellone (2008) and Marazzi (2008) hypothesise an inversion of the Fordist hierarchy between living labour and fixed capital. The new living labour centred on knowledge and information has come to predominate over fixed capital, and this would imply a tendency for capital's control over labour to decrease. Language skills, ethical tendencies, and aspects of subjectivity become means of production and outputs of the process, and this "immateriality" of the actors and the means of production would hinder the subjugation of living labour to capital, because labour is more and more connected to faculties and skills that belong to workers themselves, as well as to processes that require at least partial autonomy to execute. The subjugation of labour to capital thus would cease to be 'real' and return—as in the times prior to the development of industrial capitalism, according to Marx—to being only 'formal': co-operation and knowledge-sharing in labour relations potentially become autonomous from capital, and only thereafter is capital able to extract a surplus from the labour process, which remains indirect and external to the labour process itself.

All the elements that define the positive aspects of digital work and the 'knowledge turn' in work are controversial. First, such elements are not attributable to all knowledge or digital work. So-called immaterial labour is made up of a plurality of professional figures, among which one can identify two main heterogeneous segments (Formenti 2011): an upper social rank of high-skilled personnel, who are sources of innovation and value for firms and have some bargaining power in the labour market; a lower or medium level of routine workers devoid of bargaining power, with medium or medium–low incomes, and subject to a corporate hierarchy which gives them scant margins of creativity and autonomy. The current economic crisis restricts the former segment and expands the latter, causing a decrease in incomes and an increase in job insecurity. Contrarily to what the institutional reports state and foresee, in Western societies new employment creation mainly concerns the lower tertiary sector (Cushen and Thompson 2012), also because of the increased productivity resulting from technological innovation and the delocalisation of planning, management, control and even research activities. The dualism of the labour market in Europe has confined an increasing share of the younger generation in low-paid jobs, with poor working conditions and high levels of instability.

Second, the set of phenomena termed 'crowdworking' entails the participation in the production cycle by an increasing number of temporary collaborators, consumers and users who to a certain extent replace paid work. 'Crowdworking' may be regarded as an extreme and in itself possibly overestimated instance of the basic subject (Lehdonvirta and Ernkvist 2011; Barnes et al. 2015): employers searching for new workforces that are cheaper, more flexible, more adequately skilled and preferably all of these things. Crowdworking thus fits into the continuum of relocation (Bergvall-Kåreborn and Howcroft 2013), virtualisation and the implementation of internal markets and tendering systems that have been observed in recent years and are likely to continue. It takes different shapes ranging from tendering for professional services with different contractual arrangements to the virtual distribution of Taylorised microtasks. In all these strategies, the familiar labour process theory subjects of control, cost-cutting, industrialisation and knowledge management continue to be played out. Under conditions of intensified work and increased competition between locations and workers, this may be an inherently contradictory endeavour. Internal collaboration between locations can be undermined by internal tendering, which shifts the balancing of collaboration and competition onto project managers at the expense of a company's internal knowledge circulation.

Risk would be shifted further onto workers, and companies would escape legal regulations, social partnership relations and collective agreements. In addition, technical writers and management consultants wonder what would happen to the knowledge base of the companies. While digital crowds might bring new and more varied expertise to the job, there are concerns over the leaking of company-specific knowledge and workers' commitment.

Even companies aiming to cultivate employee commitment for these very reasons have been found to have limited success with these efforts, as the same companies are increasingly driven by financialisation, short-term performance and shareholder value or actual shareholder intervention. These dynamics put pressure on employment and working conditions, downsizing staffing levels, intensifying work, cutting cost and reducing employment security, in particular in higher wage countries. HR efforts to cultivate commitment and strong organisational cultures in these contexts are perceived as hypocritical at least and in places, downright insulting (Cushen and Thompson 2012).

Firms are able to integrate practices, social networks and forms of free cooperation in the productive process by building networks of 'extended production' that involve freelancers, users and consumers. To achieve this goal, firms adopt partially open and 'horizontal' organisational forms, giving a certain autonomy to other firms, the networks of collaborators and 'prosumers'—also sharing some of their knowledge assets with them. These organisational forms, however, do not replace, but instead integrate, corporate hierarchy.

Firms currently tend to incentivise the construction of internal pseudo-communities sustained by managerial discourses that aim to foster a sense of belonging, identity and dedication mainly based on the 'libertarian' freedom-cooperation binomial. But supposedly creative and self-managed teamwork is subject to increasing monitoring and evaluation by firms. This occurs also within knowledge-intense firms and among professionals that might be expected to be the most committed to autonomy and creativity such as, for example, R&D engineers and scientists (Gleadle et al. 2012). Scarbrough (1999) emphasises that such environments are characterised by constant tensions between settings of trust and autonomy, which favour the production of knowledge, and the rationalised and highly structured conditions which secure its appropriation. Big data collection and analysis has implications in terms of surveillance and monitoring in the workplace and the tracking of employee activities. Big data modelling solutions are making it ever easier to use quantitative or qualitative performance standards as a basis for individual benchmarking and performance profiles. Geolocation has already had a major impact in terms of the planning, monitoring and tracking of mobile workers engaged in tasks such as making deliveries, performing maintenance, repair and inspection operations at industrial plants and carrying out site visits (Valenduc and Vendramin 2016).

As Gleadle et al. 2012 emphasise, also large high-tech firms that used to adopt post-bureaucratic forms of organisation, ensuring operative autonomy to knowledge workers, have recently returned to more traditional and hierarchical models due to increasing international competition and the requests by financial shareholders of measurable goals and short-term profits.

With regard to project-based work, where projects exist, project management tends to follow, accompanied by codified formulas and routines of planning and budgeting, often in jarring conflict with the nature of work and the expectations and self-perceptions of workers in creative industries (Briand and Hodgson 2013). Evidence show that these processes also regard professions that are commonly considered to be the most creative and those for which it is more difficult to establish clear links among work time, personal performance and outputs (Brian and Hodgson's 2013). Work is constantly monitored and subject to instructions from team leaders and managers that significantly bind it, with negative consequences on projects. The autonomy of teamwork from these instructions is very limited. The partition of work into specific and measurable steps and phases, the definition of the outputs expected, and the distribution of individual responsibilities are often managed through computer software (Chen and Ross 2007; Holtgrewe 2014; Jeske and Santuzzi 2015). It is to this set of processes and mechanisms that Carr's definition of 'digital Taylorism' can be applied.

Turning to the category of so-called independent workers (freelancers, auto-entrepreneurs, etc.) it cannot be said that cooperation is their distinctive feature. As Florida (2012) notes, independent work is connoted by strong individualising pressures that jeopardise the capacity for collective action. According to Bergvall-Kåreborn and Howcroft (2013), recognition within the 'community' of producers and users is correlated to the developers' product commercialisation and their commercial value. Social relationships and cooperation, therefore, acquire an instrumental nature. As regards the autonomy of these workers, the big firms for which they work can arbitrarily and at any time decide not to accept or to withdraw their products from the market. The forms and times of work performance and the constraints on the use of creativity and the elaboration of knowledge are set by firms. Their work is highly characterised by job insecurity, uncertainty and low incomes (Pongratz and Voß 2003). In this resides the internal dialectic of independent cognitive work: the split between networking and individualism, freedom and the need to match the profiles required by firms, autonomy and individual assumption of entrepreneurial risk.

Also ambiguous is the relationship between creativity and digital work. When discussing the cognitive abilities required of the new labour force, Carr (2011) has referred to 'digital Taylorism': only rarely is digital work truly more autonomous, self-organised, variegated and creative than Fordist work; the performance of workers is organised by the planners in a way similar to that in which engineers streamlined material work in the Fordist economy. The work often consists in the incorporation of the worker's memory, mind and identity into technology (computers, software and the Web): digital media involve levels of attention, elaboration and depth lower than those required by traditional alphabetical thought, and they favour a cognitive routine focused on immediate decision-making and problem-solving. The specific component of knowledge working and the work performances related to new technologies is a set of mainly applicative skills tied to specific situations, technologies, and work processes. The thesis of an inversion of the hierarchy between living labour and fixed capital, therefore, appears overstated. It is also possible to observe the process also in reverse: it is the productive work based on the use of machines, standardised processes and softwares that incorporates working and productive intelligence, thus subsuming tasks and professional identities.

In general, recent evidence on work related to digital and 'new new' technologies clearly points to a series of trends (Warhurst and Thompson 2006; Movitz and Sandberg 2009; McDowell and Christopherson 2009; Wells, Moorman and Werner 2007; Marks and Baldry 2010; Holtgrewe 2014; Jeske and Santuzzi 2015): a weakening of the separation between personal life and work; a constant shift from stable jobs to precarious jobs with lower pay; growing pressures on workers to improve both the quantity and quality of their job performances, yet often without any compensation in terms of occupational stability, salary or career development opportunities; this divergence between requested performance and compensation individualizes job relations and diminishes workers' loyalty to and even involvement in the firm, thus reducing the potential for internal cooperation and knowledge sharing; finally, an expansion of monitoring activities, used to regulate the performances of these workers in ever greater detail, and hence diminishing (instead of increasing) their power of discretion and autonomy.

We must add to these problems the decisive issue of technological unemployment. According to an important contribution by Collins (2013), until the 1980s and 1990s mechanization chiefly displaced manual labor. Information technology has now just began to displace administrative and communicative labor, greatly downsizing the middle-class. Robotization, electronization, and the development of Artificial Intelligence, summed to mechanization, can lead to unemployment rates that, according to Collins, can reach the 50% of workforce by the year 2040. Computerization is now still in its youth and the computerization of middle-class labor is proceeding at a much faster pace than the mechanization of the manual labor force. Information Technology does not generate paying jobs at the same rate that it eliminates them. If Collin's predictions are confirmed, the effects on knowledge workers will be those of an extreme radicalization of the current negative trends that evidence highlights, regarding wage levels, employment opportunities and working conditions, and also that of a significant disappearance of cognitive work. But Collins argues that these processes could also lead to wider consequences. As the working class shrunk through mechanization, capitalism was saved by the rise of the middle class. Now capitalism cannot compensate the digitalization of middle-class labor with a corresponding creation of new jobs. According to Collins, these processes will lead to a systemic crisis of capitalism before the 21st century is over, as capitalism cannot support unemployment rates of 50% or more and systems in which wage labor is a minority of the active labor force.

According to the study on digital work by ETUI (European Trade Union Institute), a substantial proportion of the current jobs will be rendered obsolete by the latest generation of robots, due to their capacity to print 3d objects, translating documents, drafting insurance policies, taking care of elderly people in their homes, telling doctors what might be wrong with patients. The very concept of a 'job' may become outdated and replaced by an ever-shifting portfolio of commissions and projects assigned through online platforms. For what regards the forms of labour relationships, After evaluating the situation in 27 countries, Eurofound researchers identified ine new forms of employment (Eurofound 2015): *employee sharing*, where an individual worker is jointly hired by a group of employers and works within different companies on a rotational basis; *job sharing*, where a single employer hires two or more workers to fill a single job, working on a rotational basis to perform the same role within the same company; *interim management*, where a highly skilled expert is hired temporarily by an employer, often for a specific project; *casual work*, where an employment contract allows employees to be called as required on a flexible basis rather than being given regular work hours by their employer; *ICT-based mobile work*, where workers do not use their employer's premises (or their own premises if they are self-employed) as their main place of work, and spend most of their time working with information and communication technologies (computers, the Internet, e-mail and social networks). Their work differs from familiar forms of mobile work such as visiting clients or patients, working on construction sites, making deliveries or driving vehicles, and can be characterised as remote work without a fixed location; *voucher-based work*, where the employment relationship involves paying for services with a voucher purchased from a third-party organisation (generally a government body) that covers both pay and social security contributions; *portfolio work*, where a self-employed individual carries out small jobs for a large number of clients; *crowd working*, where an online platform matches employers to workers and projects are often split up into micro-tasks and divided among a 'virtual cloud' of workers; *collaborative self-employment*, observed in a number of countries where more flexible forms of collaboration (such as co-working spaces) are used to escape the confines of traditional business partnerships.

According to the Etui Report, those that will be most influenced by the emergence of a digital economy are ICT-based mobile workers, crowd working and—in certain respects—casual work. It is almost superfluous to observe how the diffusion of these two forms of collaboration implies further precarization of work relationships.

A further issue deals with unions and collective action by workers in the context of Industry 4.0. and digital work. The increasing automation and digitalization of production imply that the regulation of labor performances and labor relationships can more easily be equated, by the management, to the consequences of mere technical and neutral mechanisms (Garibaldo 2016; Hirsch-Kreinsen 2016; Magone and Mazali 2016). The current innovation cycle also involves an individualization of the relationship between workers and machines. The set of these processes affects the unions' bargaining power and the ability of collective action by workers.

During the first wave of the ICT revolution, in the 1980s, industrial firms widespread adoption of the personal computer to automatize parts of the work process, together with the diffusion of Numerical Control and CAD/CAM technologies, disrupted the traditional way of working. This disruption largely caught trade unions off guard (Bolognani et al. 2002). Evidence show that in the late 80s' there was a strong feeling of being left alone and being without the support of fellows among the workers (Pongraz and Vos 2003). This was also because the new technologies privileged an individual interaction with the machine (Hirsch-Kreinsen 2014). For workers to afford processes of disruptive change means to cope with losses regarding objective facts (risk of unemployment, unknown health risks, an upside-down change in job's content, etc.) and/or a feeling of impotence in affording processes beyond any possibility of control by the individual (Garibaldo and Bolognani 1996; Cushen and Thompson 2012). Both these elements, if present, are crucial in hindering participation in unions and collective mobilizations.

4 Conclusions: four systemic polarizations in the link between new technologies and work relationships

The current wave of technological innovation and its relationship with work and production are compounded by expressions such as Industry 4.0 and digital capitalism. The rhetoric, narratives and expectations that accompany these definitions of current changes in capitalism are not new. They confirm and expand the rhetoric and expectations that in the last few decades were linked to concepts such as post-Fordism and knowledge-based economics.

In this article, the choice has been to focus mainly on the implications that current transformations may have on work, in light of what has occurred in recent years and of the current scenario. In particular, rhetoric about digital and knowledge work have been confronted with the existing literature and evidence on this subject.

What emerged is that the whole of transformations often called the 'digital revolution' have so far not achieved any of the promises it raised. Work organization has not become more horizontal, if not partially and formally. Workers did not increase their decision-making power or their autonomy. Work has become more creative only for a fraction of highly skilled workers. On the other hand, work has become more precarious and less paid and the distinction between work time and life time has weakened. Contrarily to what is stated by the institutional readings of Industry 4.0., so far technological innovation does not replace predominantly less-skilled jobs. The creation of new jobs mainly concerns the backlog of services.

What the distance between rhetoric and the actuality of Post-Fordism and KBE shows is that improvements for workers in terms of work conditions, work performance and work relationships cannot be determined by any technical innovation in itself, being technological innovation always socially shaped. Up to now, digital innovation has predominantly produced results that firms have always pursued in the history of capitalism: to reduce workforce, wages, the guarantees and rights related to work and the bargaining power of workers; an increase in the ability to monitor and evaluate work performances; dispersion of workforce and concentration of capital (monopolies, 'winner takes all' economy), ownership and management functions; an increase of the efficiency of the production process and the management of the value chain, due to the increased production and dissemination of data. There is no reason to think that the innovations currently termed 'Industry 4.0.' can per se reverse these trends. On the contrary, its most logical effect—being unchanged all the other conditions in the relationship between work and capital—is an intensification of these results.

Observations on the future of the work made by institutions such as the WEF and the OCDE make a sort of *empatich robot* emerge as relevant figure in the labor market: according to their predictions, among the few workers who will not risk their profession is replaced by automation, there is a figure that is a strange intersection between man and machine: endowed with very high technical, informatics and computational skills, as well as relational and communicative skills.

However, if it is true that the consequences of the 'digital revolution' on work are for the most part negative, it should also be considered that the current phenomena are neither linear nor one-sided. Structural dynamics in 'digital economy', in fact, are characterised by some core ambivalences and dichotomies:

1. Socialisation of the production process/individualisation of the employment relationship. The individualisation of the employment relationship, together with job insecurity and the pressure for horizontal competition among workers exerted by firms, comprise a tendency to socialise production processes and to diffuse ownership of the means of production.
2. Cooperative exchange/market exchange. The social contents of work—relational activity, diffused knowledge, logical skills—are constantly injected into the production-consumption cycle. What the worker may perceive as cooperative exchange within the firm or between firm and its external environment is re-interpreted by firms as a market relationship. The contradictory link between 'self-production' through work and cooperation, on the one hand, and formal value of the market on the other, is currently a major driving force of productivity. The effects of this antagonism may be diverted by firms into individual outflow channels (through internal competition among workers and the individual assumption of entrepreneurial risk), but the causes of the instability that they create can hardly be removed.
3. Collective participation in decision-making/verticalisation of decision-making processes. Workers are induced to participate in formally horizontal decision-making processes, but the rhetorical invitation to participate actively is mainly functional to reorganising command methods and to a substantial verticalisation of decision-making processes. Horizontality is confined to decisions concerning the most immediate work processes, whereas on strategic choices the hierarchy and the verticality of structures are strengthened. Nevertheless, the rhetorical call for active participation is essential for firms, on both the work and consumption sides, becoming a 'competitive asset'.
4. Autonomy of labour/digital Taylorism. Work based on knowledge and partial cooperation among peers raises problems for capital from the point of view of the complete objectification of work, the measurability of work performance, and the governance of cooperative exchange. On the other hand, such problems seem currently resolved through the rigidification of immaterial ownership and the Taylorisation of a significant part of knowledge production.

Currently, firms are succeeding in making the second pole of these dichotomies (digital Taylorism, verticalisation, marketization, individualization) being dominant on the first one (autonomy, participation, peer cooperation and socialisation of production). As it has always occurred in the history of the relationship between capital and labour, the possibility that the production process will shift in a direction favourable to labour mainly depends on the capacity for coalition and conflict and on the bargaining power of the latter. These elements develop within the labour relationship also thanks to the support of dynamics (political, cultural, organisational) and actors which are external to the production process, as the history of the workers' movements demonstrates (Bartolini 2000). Therefore, positive outcomes of 'Industry 4.0.' for workers will depend on social conflict and politics.

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